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Development of Blood Donor Complication Semantic Retrieval System using the Ontology Application Management Framework

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Abstract

Blood donation is the blood transfusion from donor to the patient. The unwanted complication in blood donation process may be an impediment of donor returning to donate blood in the future. Reduction of complications not only enhances the safety of donors but also makes impression on donors which affect the likelihood of returning to the next blood donation. This paper describes the development of a prototype for Blood Donor Complication Semantic Retrieval System (BDCSRS) aimed to improved donor retention. The system development is based on the Blood Donor Complication ontology, constructed based on reviewing the related documents and blood donation staffs interview. Searching blood donor complication based on ontology has the advantage over typical database search based on keywords. Specifically, ontology allows searching complications based on concept rather than keyword matching. For example, blood bank staff searching for donors with symptoms related to pain concept can find relevant symptoms including nerve irritation and injury and tendon injury defined as its subclasses in the ontology. Ontology was constructed with HOZO ontology editor. Semantic search system was developed with the Ontology Application Management (OAM) Framework. Evaluation result demonstrated that the BDCSRS can retrieve the donor data based on different complication factors accurately. The system can help to support the staff in planning and improving blood donor services to reduce the chance of complications of blood donors.

Keywords: Blood donation, Complication ontology, Semantic web, Ontology Application Management Framework.

INTRODUCTION

Blood donation is part of the blood transfusion process that collects blood from donors, who are completely healthy, to be used in patient treatment, after the donors have registered to donate blood and had a successful physical examination. Blood bank staff insert a needle into the vein under the skin in the arm of the donor. Blood flows through the needle to the blood bag that is connected. Blood donation may cause some reactions for the donor. Examples of these reactions are bleeding under the skin, arm pain, skin allergy, nausea, numbness around the mount, vomiting, seizures and a reduction in the senses. There are several factors that may prevent donor from coming back for blood donation. Fear, scared of needle or blood, are among the negative factors. Complication is another factor that make donors scared and discourage to coming back for blood donation [1].

The incidences of complications have been studied when Sombatnimitsakul et al. found that complications occurred after plateletpheresis and red cell apheresis 3,852 out of 11,531 times (33.41%) at The National Blood Center from January to December, 2011 [2]. During August 2011 to July 2012, the donors were asked to answer questionnaires for adverse reactions after blood donations at The National Blood Center. The result found that 31.99% of donors experienced adverse reactions [3]. Also, the incidence of adverse donor reaction was studied when whole blood donors were interviewed via telephone within 24 hours after donating at the Blood Bank and Transfusion Medicine Unit, Songklanagarind Hospital and their mobile unit from September to November 2013. The result was that 17.69% of donors experienced complications [4]. Thus, reducing the number of complications can contribute to improve the donors' repetitive blood donation. Actions to reduce complications depended on the relevant blood donation database. Information systems the enabled blood bank staffs to see the hidden relationship of blood donation information can affect performance of complication reduction. For example, the staffs should be able to search for the cases where the donor symptoms indicated some forms of complications and thus can take necessary planning and action.

The National Blood Center tried to explore the occurrence of complications for blood donors at various hospital blood banks. The result found that they needed to cancel data collection because there was a very low survey response rate.

In 2013, the Thai Red Cross appointed a haemovigilance committee. This committee identified the need for blood banks to report information on the incidence of complications to The National Blood Center. Solutions or policies to reduce the incidence of complications were prepared from this information. In 2015, The National Blood Center produced a haemovigilance guideline for classification of complications related to blood donation in order to standardize the reporting of this information [5].

Nowadays, information on blood donors and blood donation is managed by the blood bank information system. Unfortunately, this information system does not record the complication information of donors because the system has been in use for a long time before the above guideline policy. To record complications, blood bank staff record the complications of each donor into an empty remark field in order to use the information for the blood donor service on the next occasion. Recording such information is not predetermined by the database. The system also cannot retrieve and summarize information to generate reports. Blood bank staff must search and summarize information manually.

Information that is retrieved from the information system is usually retrieved from data which is stored in the database. The database has a pre-structured design. The information is retrieved using a keyword that is identified by the user or application developer. Information is discovered by comparing the differences of characters in keywords, regardless of the relevant meaning of keywords [6]. Finding data based on meanings can be achieved by the use of data structures that contain the relevant meaning in the form of an ontology that is behind a semantic search [7].

Semantic searches have been applied in several research works. For example, a semantic product search system was developed to offer products that met customer needs by the matching a customer’s personal profile data and product information [8]. A semantic search system was developed to increase efficiency when searching for movie information so users could use their natural language format to search [9]. A drought management system was developed using a semantic search to show related information for consideration of drought management [10]. Another semantic search system allows searching for all travel related information to improve travel planning efficiency for tourists [11]. Semantic systems were also developed to search for related knowledge on traditional Chinese medicine or cultural and historical bell objects [12, 13].

In this research, a semantic retrieval system was developed based on ontology and the Resource Description Framework (RDF) standard to allow blood donation staffs to discover the relationships of the data that associated with complication of donors. Blood donation staffs may be able to get results that are not visible to the common search in a typical database search system. Searching complications based on ontology has several advantage over typical database search based on keywords. First, ontology allows searching complication based on concept defined by domain experts rather than using arbitrary keywords, which can lead to retrieval of more relevant results. Second, ontology allow for intelligent search that utilized inferencing over subclass-of relationship between concepts. For example, blood bank staff searching for donors with symptoms related to pain concept can find relevant symptoms including nerve irritation and injury and tendon injury defined as its subclasses in the ontology.

This research aimed to develop a BDCSRS prototype to support blood bank staff in searching donor complications. The prototype was developed using the Ontology Application Management (OAM) Framework, which is an application framework that simplifies ontology-based application development [14]. Blood donation staff could use information obtained from BDCSRS to create a taking care plan for both new donors and regular donors. As a result, reducing the incidence of complications would help reducing the donor's fear and providing a good experience with donors. This would affect the increment for donors' repetitive blood donation. Moreover, the created ontology can be shared and reused for other applications.

ONTOLOGY AND SYSTEM DEVELOPMENT

The BDCSRS was developed in 3 steps. First, information relevant to the blood donation process and donor complications were collected. Second, the blood donor complication ontology was constructed. Finally, the semantic retrieval system was developed with an OAM framework.

Collecting related information

Information collection consisted of two parts. First, blood donation information and complications were collected from reference documents. Blood donation information was collected from blood donor selection guidelines and blood donor registration forms [15]. Complication information was collected from guidelines on haemovigilance [16]. The collected information was summarized to prepare for interviews with blood donation staffs. Second, five blood bank staffs were interviewed about their blood donation process, related blood donation information and blood donation complications. Results of the blood bank staff interviews were summarized and preprocessed to construct a blood donor complication ontology in the next step.

Constructing the ontology

Figure 1 shows the main classes of the blood donor complication ontology that was constructed with a HOZO-ontology editor [17]. The nine main classes of ontology consisted of Severity, BloodGroup, DonationCategory, DonationPlace, Complication, Donation, Rh, Career, and DonorCategory.

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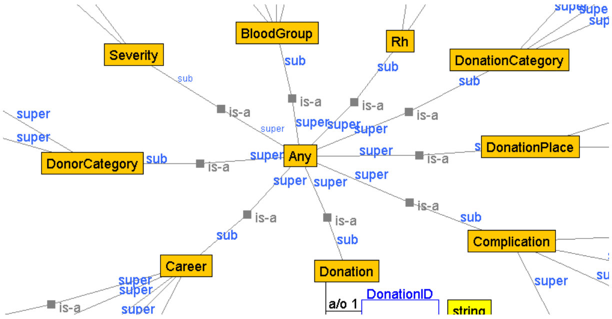


Figure 1: Blood donor complication ontology

The *Complication* class, shown in Figure 2, was the main class which formed the key concept of this ontology. It held several categories of adverse reactions. The complication class was divided into four subclasses of complications which were: Local symptoms, Generalized symptoms, Related to apheresis, and Others.

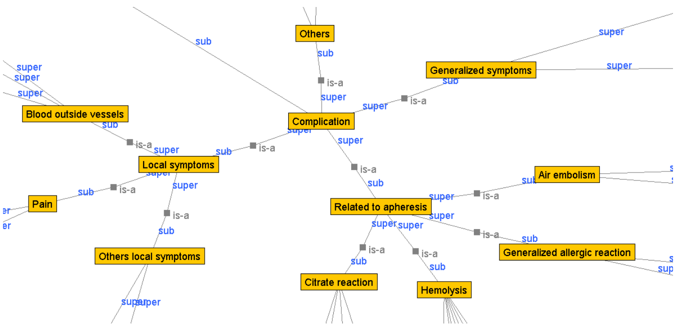


Figure 2: Subclass of complication

The *Local symptoms* subclass included complications that arise directly from the needle being used for blood collection. It was divided into three subclasses which were:

1) Blood outside vessels was divided into 3 subclasses which consisted of a) bruise and hematoma, b) arterial puncture and c) delayed bleeding.
2) Pain was divided into two subclasses that were specified and not-specified. The specified subclass consisted of a) nerve, which was also divided into nerve irritation and nerve injury, and b) tendon injury. The not-specified subclass had a subclass that was painful arm.
3) Other local symptoms had two subclasses which were a) thrombophlebitis and b) local allergy.

The *Generalized symptoms* subclass was symptoms that could cause a vasovagal reaction. It was divided into 2 subclass which were:

1) Symptoms subclass was generalized symptoms. Examples of generalized symptoms were adverse reaction, nausea, vertigo and restlessness.
2) Vasovagal reaction subclass was the severity of the vasovagal reaction which was divided into 4 subclass which consisted of a) immediate vasovagal reaction, b) immediate vasovagal reaction with injury, c) delayed vasovagal reaction and d) delayed vasovagal reaction with injury.

The *Related to apheresis* subclass included symptoms caused by donating blood specific parts. Whole blood was taken through a production process to obtain blood components such as platelets. But, donating blood specific parts uses a blood cell separator machine to separate specific blood components as required. Symptoms that related to apheresis were divided into 4 subclasses that were:

1) Citrate reaction subclass.
2) Hemolysis subclass.
3) Generalized allergic reaction subclass.
4) Air embolism subclass.

The *Other complication* subclass includes symptoms that were not mentioned in the three categories above. These complications consisted of:

1) Hypovolemia subclass that was blood volume condition where a rapid decrease progressed until fainting occurred.
2) Bodily symptoms subclass that was a result of the mind and stress.

Other main classes as follow:

The *Severity* class represented the severity of adverse reactions arising from blood donations. It was be divided into two subclasses that were:

1) Severe. The severe subclass had no subclass
2) Non-severe. The non-severe subclass was divided into mild and moderate.

The *BloodGroup* class represented the blood groups of the ABO system which was the most important system in blood donation. It consisted of four subclasses that were A, B, O and AB.

The *Rh* class represented another blood system which was next most important after the ABO system. It could be divided into two subclasses that were the positive subclass and the negative subclass.

The *DonationCategory* class represented the type of blood donation which was divided into whole blood, platelet apheresis and plasma apheresis.

The *DonationPlace* class described the place where blood was donated. This class consisted of two sub-classes that were the InPlace subclass and the Mobile subclass. The InPlace subclass referred to any unit located at a hospital. The Mobile subclass referred to any donation unit that temporarily operated outside a hospital.

The *Career* class was a class that represented the donor's career such as government official, teacher, student, agriculturalist or merchant.

The *DonorCategory* class described the type of donor and consisted of NewDonor and RegularDonor subclasses. A NewDonor was a person who donated blood for the first time. A RegularDonor was a person who had experience in blood donation.

The *Donation* class was a class that described blood donation information from donors. This class consisted of many attributes including donation_id, donor_name, donation_category, place, complication, severity, bloodgroup, rh, career, age, donor_category, donor_weight, donation_no, and blood_pressure.

The blood donor complication ontology was exported to a Web Ontology Language (OWL) file which was used as the knowledge base for the BDCSRS.

Developing the semantic retrieval system

The BDCSRS prototype was developed using the Ontology Application Management (OAM) Framework. The OAM framework [14, 18] is an application development platform aims to simplify creation and adoption of an ontology-based Semantic Web application. The application framework differs from the existing tools in two main aspects. First, it is an integrated platform that supports both RDF data publishing from database based on domain ontology and processing of the published data in ontology-based Semantic Web applications, i.e. semantic search and recommender system applications. Second, the framework provides some reusable and configurable data and application templates that can be customized for different domain ontologies using configuration GUIs. Thus, it does not require user's programming skill in building an ontology-based Semantic Web application prototype.

The OAM framework introduces intermediate layers between user application and existing Semantic Web programming and development environment. Design of the framework is based on three principles: ontology-based data publishing and access, abstraction and interoperability. OAM requires ontology as a central structure for publishing RDF data from database and as a means to access the published RDF data. The layers introduced by OAM aim to hide complexity of the underlying Semantic Web data standards and models. The framework is designed to be independent of the underlying implemented systems. Thus, wrapper architecture is required for interoperation with different data formats and systems. Figure 3 show a layered architecture of the OAM framework. Figure 4 show the architecture and some applications of the OAM framework.

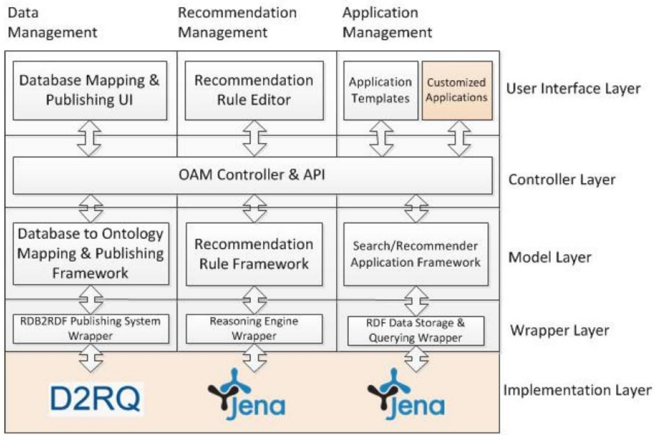


Figure 3: Layered architecture of the OAM framework [14]

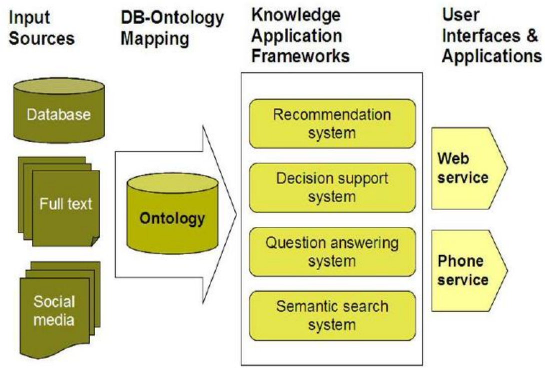


Figure 4: Applications of OAM architecture [19]

The OWL file, which was exported from HOZO editor, was used to ontology as a central structure for BDCSRS. The main step in the BDCSRS development was the database to mapping method, shown in Figure 5.

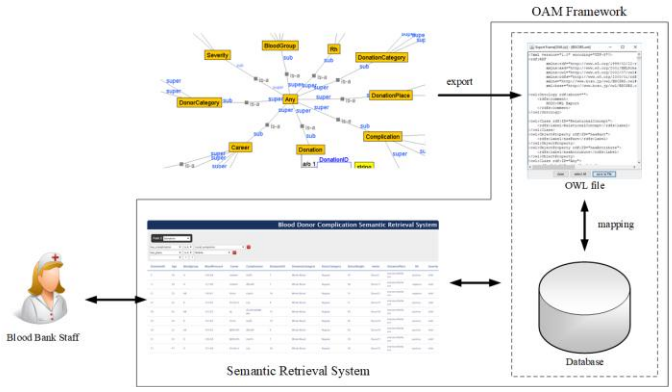


Figure 5: BDCSRS architecture

The database to ontology mapping method followed 3 steps. First, the main classes of the ontology were defined to connect with data tables in the database, which is called class-table mapping. Second, the properties of each class were defined to connect with columns of tables in the database, which is called property-column mapping. Finally, the data in each column of the table were defined for each subclass of the ontology, which is called vocabulary mapping. Figure 6-8 show examples of the database to ontology mapping process. After the databased-ontology mapping step, the database data was transformed to RDF data and stored in a RDF database. The semantic search system template of OAM allows retrieval of the data using SPARQL via a form-based interface.

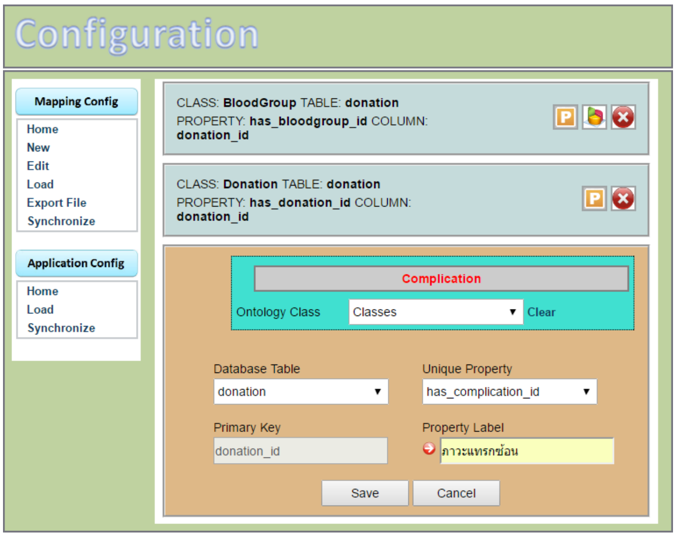


Figure 6: Class-Table mapping

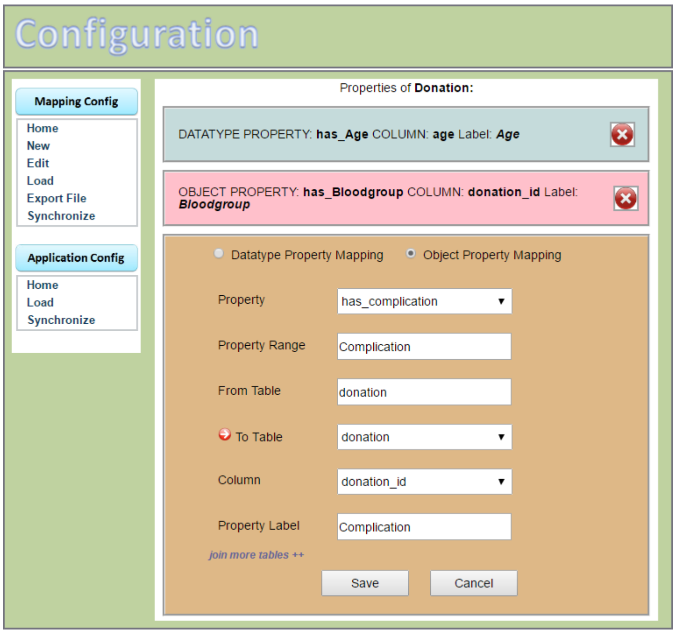


Figure 7: Property-Column mapping

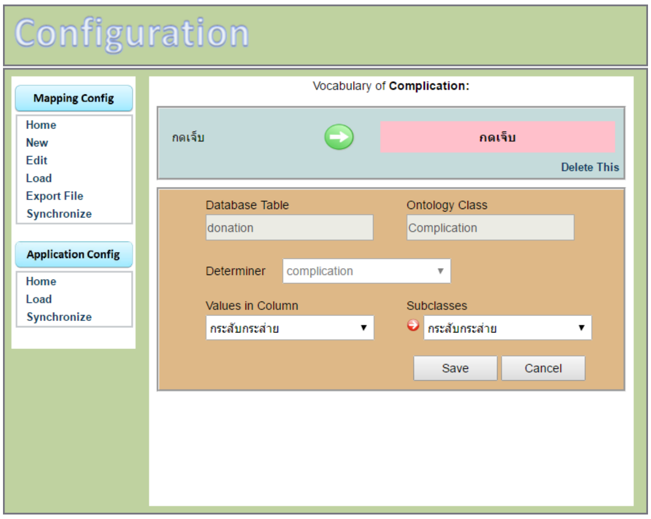


Figure 8: Vocabulary mapping

SEMANTIC RETRIEVAL AND EVALUTION

An evaluation was conducted over the blood donor database, which included their respective information and their symptoms, were simulated from blood donation application forms containing 100 data records of blood donors. Five test queries were defined based on the ontology concepts and properties. The retrieval results were assessed by 30 blood bank staffs. Generally, the staff's comments were that the system provides beneficial results which could be used to take care for donors. Such result not only could be used as information to support taking care of blood donation donors, but also could be used to create a plan for reducing the incidence of complications.

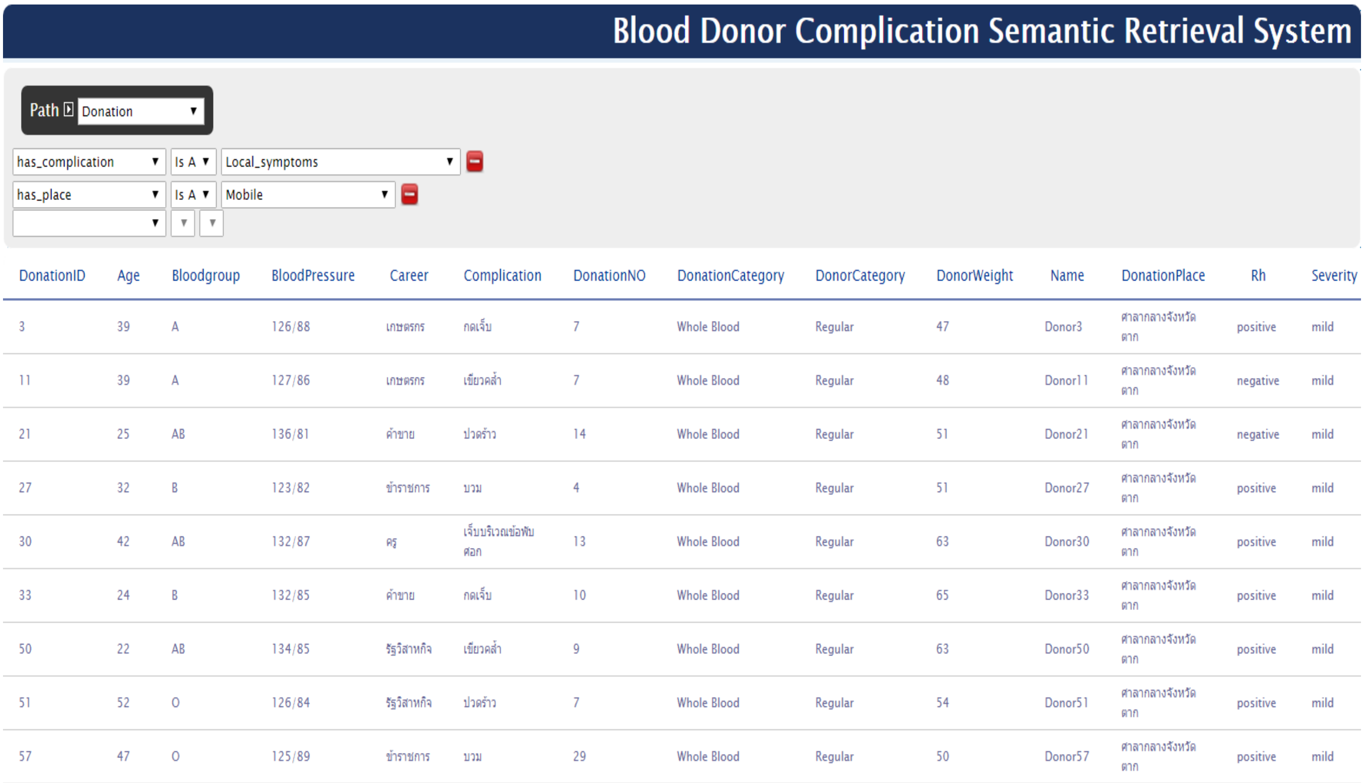
This study used the precision and recall value to evaluate the accuracy of the BDCSRS. Precision is the ratio of relevant items retrieved divided by retrieved items. Recall is the ratio of relevant items retrieved divided by relevant items [20].

In searching donor complications, a blood bank staff can choose a category of information by identifying one or more conditions for information retrieval, i.e. different search parameters. Then the system displays the result of the semantic information retrieval base on identified condition.

For example, Figure 9 shows the results of semantic retrieval from donation category and two identified conditions which were: a donor who experienced the complication in local symptom group and donor who donated blood at a mobile unit of a blood bank.

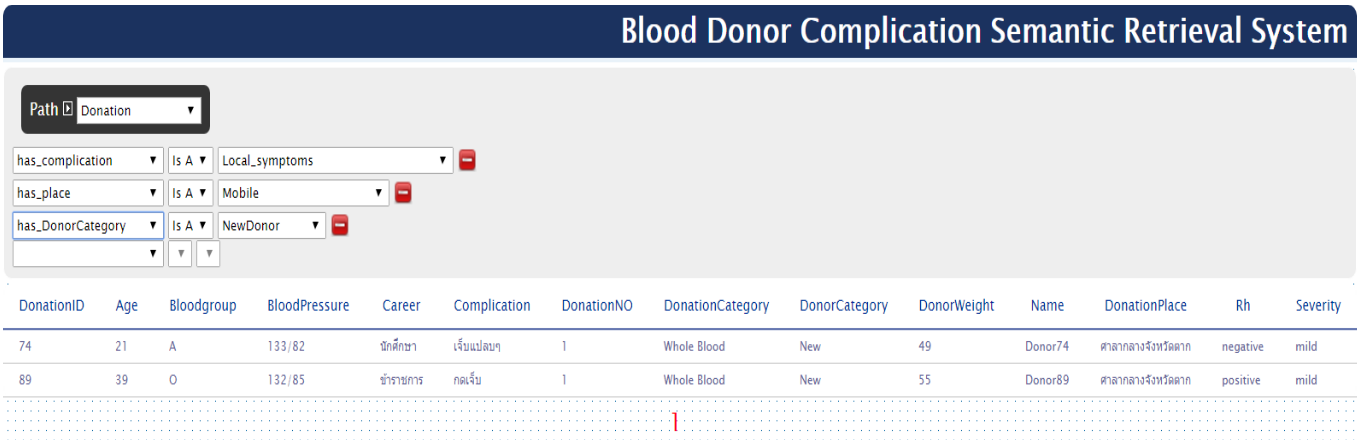
Figure 10 shows search results from the BDCSRS with the added a condition to retrieve of new donor only. The BDCSRS retrieved new donors who experienced the complication and donated blood at a mobile unit of the blood bank.

Table 1 shows the precision and recall evaluations of the search results retrieved using five test queries. These result showed that the BDCSRS accurately retrieved the complication information using the semantic information retrieval approach.



DonationID	Age	Bloodgroup	BloodPressure	Career	Complication	DonationNO	DonationCategory	DonorCategory	DonorWeight	Name	DonationPlace	Rh	Severity
3	39	A	126/88	เกษตรกร	กดเจ็บ	7	Whole Blood	Regular	47	Donor3	ศาลากลางจังหวัดตาก	positive	mild
11	39	A	127/86	เกษตรกร	เขียวคล้ำ	7	Whole Blood	Regular	48	Donor11	ศาลากลางจังหวัดตาก	negative	mild
21	25	AB	136/81	ค้าขาย	ปวดร้าว	14	Whole Blood	Regular	51	Donor21	ศาลากลางจังหวัดตาก	negative	mild
27	32	B	123/82	ข้าราชการ	บวม	4	Whole Blood	Regular	51	Donor27	ศาลากลางจังหวัดตาก	positive	mild
30	42	AB	132/87	ครู	เจ็บบริเวณข้อพับศอก	13	Whole Blood	Regular	63	Donor30	ศาลากลางจังหวัดตาก	positive	mild
33	24	B	132/85	ค้าขาย	กดเจ็บ	10	Whole Blood	Regular	65	Donor33	ศาลากลางจังหวัดตาก	positive	mild
50	22	AB	134/85	รัฐวิสาหกิจ	เขียวคล้ำ	9	Whole Blood	Regular	63	Donor50	ศาลากลางจังหวัดตาก	positive	mild
51	52	O	126/84	รัฐวิสาหกิจ	ปวดร้าว	7	Whole Blood	Regular	54	Donor51	ศาลากลางจังหวัดตาก	positive	mild
57	47	O	125/89	ข้าราชการ	บวม	29	Whole Blood	Regular	50	Donor57	ศาลากลางจังหวัดตาก	positive	mild

Figure 9: Query result (has_Complication -> Local symptoms and has_place -> Mobile)



DonationID	Age	Bloodgroup	BloodPressure	Career	Complication	DonationNO	DonationCategory	DonorCategory	DonorWeight	Name	DonationPlace	Rh	Severity
74	21	A	133/82	นักศึกษา	เจ็บแปลบๆ	1	Whole Blood	New	49	Donor74	ศาลากลางจังหวัดตาก	negative	mild
89	39	O	132/85	ข้าราชการ	กดเจ็บ	1	Whole Blood	New	55	Donor89	ศาลากลางจังหวัดตาก	positive	mild

Figure 10: Query result (has_Complication -> Local symptoms and has_place -> Mobile and has_DonorCategory -> NewDonor)

Table 1: Test queries and evaluation results

Query	Numbers of results	Precision value	Recall value
1. has_Complication IS-A Local_symptoms and has_place IS-A Mobile	16	1.0	1.0
2. has_Complication IS-A Local_symptoms and has_place IS-A Mobile and has_DonorCategory IS-A NewDonor	2	1.0	1.0
3. has_Complication IS-A Generalized_symptoms	32	1.0	1.0
4. has_Complication IS-A Ralated_to_apheresis	11	1.0	1.0
5. has_Complication IS-A Citrate_reaction	6	1.0	1.0

CONCLUSION

This study presented a BDCSRS prototype development using an OAM framework to retrieve the complication information of blood donors. The BDCSRS architecture uses a complication ontology that included nine main classes mapped to information that was stored in the database. One hundred cases of blood donor complication information were simulated and used to evaluate semantic information retrieval from the BDCSRS prototype with precision and recall values. The result showed precision value equal to 1.0 and recall value equal to 1.0. This evaluation result showed that the BDCSRS prototype retrieved the complication information of blood donors accurately. Blood bank staff can therefore report complication information to the Nation Blood Centre using information retrieval from the BDCSRS. This information was also beneficial to blood bank staff to reduce the incidence of complications. In addition, the created blood donor complication ontology can be shared and reused for other applications.

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